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A review on factors for maximizing solar fraction under wet climate environment in Malaysia

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ABSTRACT

Solar energy is the most promising source of clean, renewable energy and it has the greatest potential of any power source to solve the world's energy problems. However, the problem, is how best to harness this vast amount of solar energy. Nevertheless, even if highly efficient Concentrating Solar Power (CSP) could be made cheaply, there would be considerable change in solar power. This technology is expected to be more efficient and to achieve a manufacturing cost of less than $1/W near future. This paper reviews and elaborates the methodology utilized to design and fabricate the solar dish concentrator and outlines the parameters that can be used to increase the efficiency of solar fraction in parabolic dish concentrator under wet climate environment in Malaysia. The study finally provides ideas to the continually increasing ability of these technologies to concentrate and harness solar energy for electricity production and thus eliminate the growing concern over climate change and how it will hurt the region's environment, human health and economy.

Contents

1. Introduction 2243
2. Principle of solar dish energy concentration 2244
3. Solar fraction 2244
4. Position of the sun and solar declination 2244
5. Parameters for maximizing solar fraction using solar dish 2245
   5.1. Diameter of the dish 2245
   5.2. Material of the reflector 2245
   5.3. Focal length of the dish 2245
   5.4. Calculating a parabolic dish's focal point 2245
   5.5. Rim angle of the dish 2245
   5.6. Size of focal spot 2245
   5.7. Shape of the concentrators 2246
   5.8. Tracking mechanism 2246
6. Solar radiation 2246
7. Irradiance measurements 2247
   7.1. Data logger 2247
   7.2. Thermocouple 2247
8. Errors in the design 2247
9. The global market in solar-thermal power 2247
10. Conclusion 2248
    References 2248

1. Introduction

Naturally, there is ongoing research on renewable energy (RE) technologies throughout the world [1–9]. These technologies

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have proven to be efficient, reliable and cost effective (in the long run). The developments of Concentrating Solar Power (CSP) technologies, with the focus on dish concentrator, have led to the continually increasing ability of these technologies to concentrate and harness solar energy for electricity production. This paper is mainly focused on aspect maximization of solar fraction in wet climate in Malaysia using different dimensions of solar dish concentrator. More specifically, the work outlines the parameters that can be used to increase the efficiency of solar fraction in parabolic dish concentrator. The solar flux concentration ratio C typically obtained at the focal plane varies between 30 and 100 suns for trough systems, 500 and 5000 suns for tower systems, and 1000 and 10,000 for dish systems [10]. Higher concentration ratios imply lower heat losses from smaller receivers and, consequently, higher attainable temperatures at the receiver.

The solar concentrating systems described have been proven to be technically feasible in large-scale experimental demonstrations aimed mainly at the production of solar-thermal electricity in which a working fluid (typically air, water, helium, sodium, or molten salt) is solar-heated and further used in traditional Rankine, Brayton and Stirling cycles [11].

2. Principle of solar dish energy concentration

The conventional method for concentrating solar energy, i.e. collecting solar energy over some large area and delivering it to a smaller one, is by parabolic-shaped mirrors or using reflectors in parabola [10]. As mentioned before, a parabola focuses rays parallel to its axis into its focal point. However, sun rays are not parallel. To a good approximation they can be assumed to originate at a disk which subtends the angle $\theta = 0.0093$ radian. When a perfectly specula reflective parabolic of focal length f and rim angle Φ_{rim} is aligned to the sun, reflection of the rays at the focal plane forms a circular image centred at the focal point with diameter d as shown in Fig. 1. It has the diameter,

$$d = \frac{f \times \theta}{\cos\phi_{\mathrm{rim}}(1 + \cos\phi_{\mathrm{rim}})} \tag{1}$$

According to the Steinfeld and Palumbo [10], the radiation flux intensity on this circle is maximum and uniform in the paraxial solar image (the "hot spot"). It decreases for diameters larger than $f \times \theta$ as a result of forming elliptical images. The theoretical concentration ratio C at the hot spot is defined as the ratio of the radiation intensity on the hot spot to the normal beam insolation, and is approximately

$$C \sim \frac{4}{\theta^2}\sin^2\phi_{\mathrm{rim}} \tag{2}$$

For example, for a rim angle of 45°, the theoretical peak-concentration ratio exceeds 23,000 suns, where 1 sun refers to the normal beam insolation of 1 kW/m^2. The thermodynamic limit for solar concentration is given by the factor $\sin^{-2}\theta \sim 46{,}000$ suns. The achievable concentration ratios are much smaller due to the losses in practice. Losses in power and concentration are due to geometrical imperfections (such as a segmented approximation to the exact parabolic profile, facet misalignments, structural bending and deformations), optical imperfections (such as poor reflectivity and specularity of the mirrors and glass absorption), shading effects (such as shading caused by the receiver and the non-reflective space or frame around each mirror facet), and tracking imperfections [10,12] (Fig. 2).

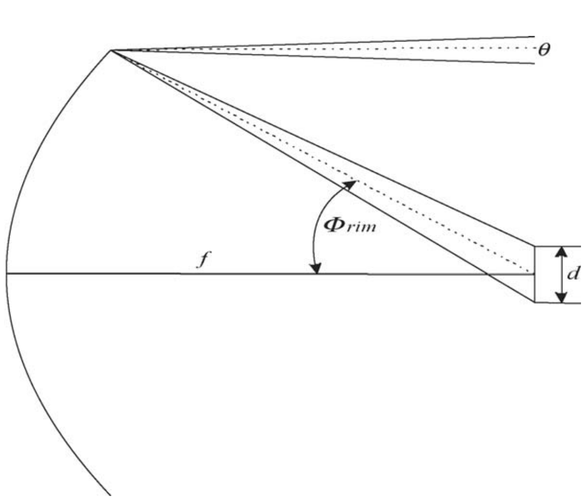

Fig. 1. Concentration of sunlight by a parabolic dish of focal length f and rim angle Φ_{rim}.

3. Solar fraction

In discussing solar energy, the solar fraction (SF) is the amount of energy provided by the solar technology divided by the total energy required [13]. The solar fraction thus is zero for no solar energy utilization, to 1.0 for all energy provided by solar. The solar savings fraction of a particular system is dependent on many factors such as the load, the collection and storage sizes, the operation, and the climate. As an example, the same solar-thermal water heating system installed in a single family house in hot climate might have SF = 0.75, while in a much colder and cloudier climate, might only have a solar fraction of SF = 0.30 or so. Great care is thus needed in designing such systems, and in evaluating their economics. To increase the solar savings fraction, energy conservation measures should be employed first before expanding the size of the solar energy collection system. Doing so reduces the need for hot water or space heating, for example, and typically provides the best economic return on the total investment, including the solar energy system.

4. Position of the sun and solar declination

The position of the sun is essential for many further calculations for solar energy systems. The two angles sun height (solar altitude or elevations) γ_ζ and solar or sun azimuth α_ζ define the position of the sun, as shown in Fig. 2 [14]. The sun height is defined as the angle between the centre of the sun and the horizontal seen by the observer. The azimuth angle of the sun describes the angle

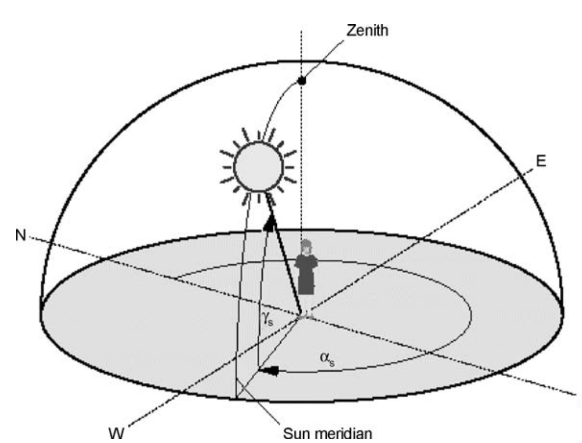

Fig. 2. Definition of the angles for the description of the position of the sun [15].

between geographical north and the vertical through the centre of the sun [15].

As a result of the earth's axial rotation and its revolution around the sun, the sun is constantly changing its position in the sky. This motion of the sun determines the amount of solar energy incident upon a collector located on the earth's surface. The area of a solar collector exposed to the direct solar radiation depends upon the angle between sun and the collector. Similarly, the length of time for collecting solar energy (day length) depends upon the sun celestial motion. On the other hand, orientation of permanent collectors, focusing of concentrating collectors and mode of solar tracking are major factors considered for availability of on solar energy. The solar declination δ is the angle formed by the line from the centre of the earth to the centre of the sun on a particular day and the plane containing the earth equator. The value of declination angle ranges from 0° at the spring equinox, to +23.44° at the summer solstice, to 0° at the fall equinox, to 23.44° at the winter solstice [16].

5. Parameters for maximizing solar fraction using solar dish

This section identifies some of the parameters that affected in maximising the solar fraction based on a case study carried out from three parabolic dishes made of different types of materials and reflectors. Two dishes made of fibre glass are supported firmly with a rigid frame and other one is shiny Stainless Steel frame. It is made, such a way that its size and shape would form a point focus when exposed to sun in the normal direction. Therefore, it is worth to note that the following parameters might not give the same outcomes for a larger scale solar dish.

5.1. Diameter of the dish

The collector aperture affects both the optical efficiency and the concentration ratio of the dish. Smaller collector aperture would have smaller geometric factors (aperture area loss due to abnormal incidence effects) and ultimately lead to higher optical efficiency. Diameter of the dish is selected by giving fixed values to dish concentrators and by using a software[1] and Eq. (3), the focal point of the dish can be determined. Practically, diameter of the dish is measured at the aperture from two positions, which are about normal to each other.

5.2. Material of the reflector

One of the critical tasks in developing a solar concentrator is to identify a suitable and economical reflective material for this application. Although, there are many reflective materials that can be used in solar concentrator's surface and widely available in the market, nearly all the existing concentrators use a reflective surface of aluminium or silver, deposited on glass or plastic. The most durable reflective surfaces have been silver/glass mirrors, similar to decorative mirrors used in the home. However, the most common reflective material used is plain aluminium foil due to the higher reflectivity and can easily be glued very well with white glue or wheat paste (http://www.solarpaces.org/, http://solreka.com, and http://solarcooking.wikia.com/). Reflective material or the reflecting surface may deteriorate when exposed to the weather. So the material must be long life and low cost. In this work, aluminium film has been used in the dish concentrator as a reflector and pasted with white glue. Polished aluminium surfaces have reflectance in the range of 0.8–0.9 [17]. The concentrator needs curved reflectors, thus, the aluminium foil will give excellent parabolic shape with light weight. In other case we used shiny stainless steel surface in the dish concentrator. The surface of the dish concentrator is polished and solar beams can be reflected towards the focus. Like aluminium foil, polished stainless steel surfaces also have very high reflectivity [18].

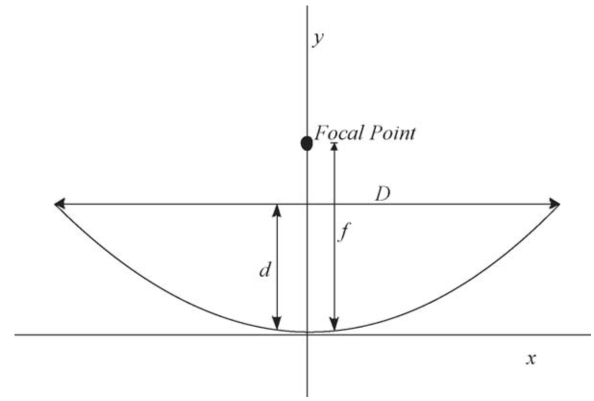

Fig. 3. Shape of parabola.

5.3. Focal length of the dish

The ray of light parallel to the axis of an aluminium foiled parabola will all be reflected and focused at a focal point. However, this requires continuous adjustment of position to maintain the focus as the sun moves though the sky [19]. The parabola has the unique property that an on-axis parallel beam of radiation will be reflected by the surface and concentrated at its focus (or conversely, a point source located at the focus will produce a parallel beam on reflection [20]).

5.4. Calculating a parabolic dish's focal point

Calculating the correct focal point of the dish is very important for accurate reading of solar radiation. Even if the dish is a standard manufactured unit, they will vary from dish to dish due to tolerance. To calculate the focal point (f) of the dish, the diameter (D) and depth (d) of the dish have to be measured, as shown in Fig. 3.

The following equation can be used to determine the correct focal point.

$$f = \frac{D^2}{16d}; \tag{3}$$

where f: focal point of dish, D: diameter and d: depth [21].

Depending on the size and shape of the parabolic concentrator, the focal point and depth can be varied from the above calculation. Parallel radiation may be concentrated with solar reflectors. A parabolic trough concentrates light on a line and a parabolic dish concentrates light on a point. Sunlight radiation is essentially parallel it may be concentrated at the focal point of the lens.

5.5. Rim angle of the dish

This is the angle subtended by the line joining a point on the aperture of the dish to the focal point with the axis of the parabolic, measured with respect to focal plane. As shown in Fig. 4, for the same aperture, various rim angles are possible and it also shows that, for different rim angles, the focus-to-aperture ratio which defines the curvature of the parabola is changing [22].

5.6. Size of focal spot

When designing the concentrator we have to assume that, the smaller the focal point or spot, the higher the temperature. So the

[1] http://mscir.tripod.com/parabola/.

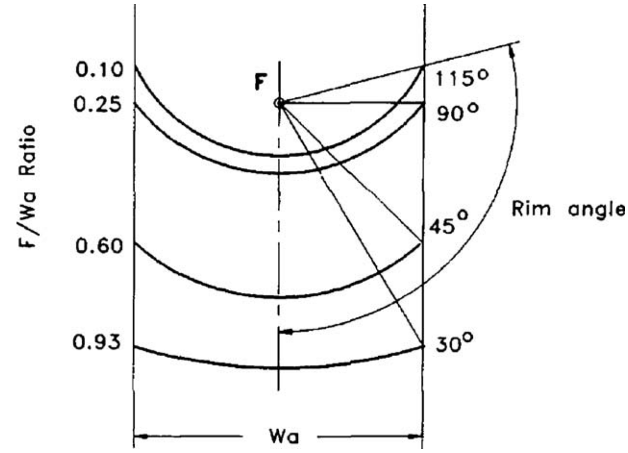

Fig. 4. Parabola focal length and curvature [22].

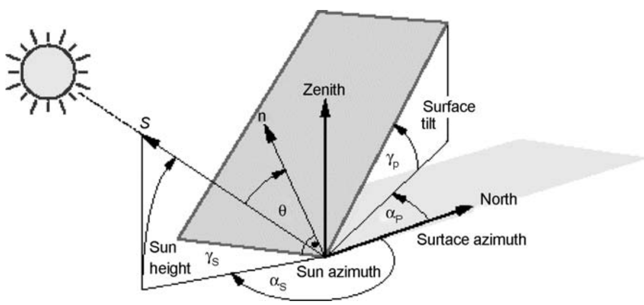

Fig. 5. Angles to define the position of the sun and the orientation of a tilted plane. (source: http://www.volker-quaschning.de).

dish design must be such a way that we get the smallest focal point, because it will give higher temperature at the focal point. However, due to the high level of accuracy required in the manufacture of parabolic, a minimal focal point is very difficult to obtain.

5.7. Shape of the concentrators

The aims of the concentrators are to collect and direct the sun radiation of the low density to the small area, which increases several hundred times the density of the radiation. Increased solar radiation density is a prerequisite to its more efficient conversion into the electricity. The most important parameters that increase the quantity and density of the concentrated energy in the focus of the reflectors are concentrator projected area, secular reflection and accuracy of the reflector/mirror making. In practice, its own area, weight, and strength of the material and stiffness of the construction limit the size of concentrator. The greater the area of the mirror is, the greater the weight will be, so the strain in material will become greater than allowed in case of strong wind [23] (Figs. 5 and 6).

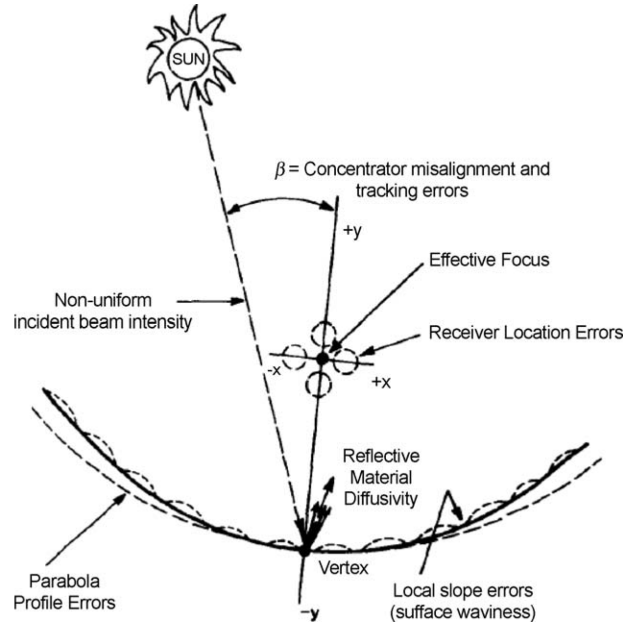

Fig. 6. Description of potential errors in parabolic collector [26].

5.8. Tracking mechanism

During the day, the sun has different positions. So, it is necessary for the dish to be pointed directly towards the sun for the highest efficiencies to be achieved. Therefore, a tracking system is required. Although the present study did not use any tracking devices for concentrator rather it tracked the sun's position manually. It has been done by finding brightest point at the focal point and shadows of the concentrator.

6. Solar radiation

The spectrum of the radiation emitted by the sun is close to that of a black body at a temperature of 5900 K [24]. About 8% of the energy is in the ultra-violet region, 44% is in the visible region and 48% is in the infra-red region. The solar constant I_0, is the beam solar radiation outside the Earth's atmosphere when the sun is at its mean distance from the Earth. Its value is $I_0 = 1.37 \pm 0.02$ kW/m^2. Variations in the distance of the sun from the Earth due to the ellipticity of the Earth's orbit cause the actual intensity of solar radiation outside the atmosphere to depart from I_0, by a few percents. The processes affecting the intensity of solar radiation that are important in solar energy work are scattering, absorption and reflection. Reflection occurs in the atmosphere and on the Earth's surface. The scattering of solar radiation is mainly by molecules of air and water vapour, by water droplets, and by dust particles. This process returns about 6% of the incident radiation to space, and about 20% of the incident radiation reaches the Earth's surface as diffuse solar radiation [24]. Table 1 shows some of the basic units of solar radiation.

Table 1
Basic units of solar radiation.

Parameter	Symbol	Definition
Irradiance	G	Intensity of solar radiation received (power)
Irradiation	H	Quantity of solar energy received by a surface over a given period (energy)
Solar constant	G_{SC}	Value of irradiance at the top of the atmosphere
Peak value at sea level	G_0	Value of irradiance at sea level of surface of earth
Nominal value	–	Rated value

The maximum irradiance can usually be obtained by a surface that is perpendicular to the sun. Since the position of the sun changes during the day and year, only a two-axis tracked surface gets the maximum irradiation. There, the annual irradiation can be more than 30% higher than at a non-tracked surface. A one-axis tracked surface has an irradiation gain in the range of 20%. Near the equator, the optimal orientation of a non-tracked surface is nearly horizontal. In the Northern Hemisphere, it should be tilted towards the south, and in the southern hemisphere, towards the north. The optimal tilt angle increases with higher latitudes, and is higher in winter than in summer.

7. Irradiance measurements

Outside the atmosphere, the annual solar irradiation is about 12,000 kWh/m^2 (8760 h at 1367 W/m^2). At every site on the earth, half of the year is night, with no sunshine. The atmosphere reduces the irradiance at least by 25%. Clouds and dust increase this reduction so that the best sites on earth, in extreme desert areas, receive an annual solar irradiation which can be more than 2500 kWh/m^2. On the other hand, there are cloudy sites at high latitudes with an annual irradiation far below 1000 kWh/m^2. On-site measurements are the only way to estimate the solar potential for solar systems [25].

7.1. Data logger

A data logger is an electronic device that records data over time or in relation to location either with a built in instrument or sensor or via external instruments and sensors (http://www.electricity-forum.com) increasingly, but not entirely and they are based on a digital processor (or computer). It is generally small, battery powered, portable and equipped with a microprocessor, internal memory for data storage and sensors. Some data loggers interface with a personal computer and utilize software to activate the data logger and view and analyze the collected data, while others have a local interface device (keypad, LCD) and can be used as a stand-alone device (http://www.omega.com). Data loggers vary between general purpose types for a range of measurement applications to very specific devices for measuring in one environment only. It is common for general purpose types to be programmable however many remain as static machines with only a limited number of changeable parameters. Electronic data loggers have replaced chart recorders in many applications.

One of the primary benefits of using data loggers is the ability to automatically collect data on a 24-h basis. Upon activation, data loggers are typically deployed and left unattended to measure and record information for the duration of the monitoring period. This allows for a comprehensive, accurate picture of the environmental conditions being monitored, such as air temperature and relative humidity.

7.2. Thermocouple

Thermocouples are available either as bare wire 'bead' thermocouples which offer low cost and fast response times or built into probes (http://www.picotech.com) A wide variety of probes are available, suitable for different measuring applications (industrial, scientific, food temperature, medical research, etc.). One word of warning: when selecting probes take care to ensure they have the correct type of connector. The two common types of connector are 'standard' with round pins and 'miniature' with flat pins; this causes some confusion as 'miniature' connectors are more popular than 'standard' types. When choosing a thermocouple consideration should be given to the thermocouple type, insulation and probe construction. All of these will have an effect on the measurable temperature range, accuracy and reliability of the readings. Some of the thermocouple types are type K, E, J, N, B, R and S. (http://www.picotech.com).

8. Errors in the design

There may be several types of errors or imperfection during and after the assembly of concentrators. Special consideration and detailed knowledge of the effect of various errors, their improvement must be highlighted during the whole project. The following errors are some of the main concern in the project.

Local slope errors: Surface waviness of the reflector may result from distortion of its surface during manufacture.
Profile errors: The average shape of the reflector (obtained by averaging the local slope errors or waves) may differ from a parabola. This may be due, for example, to distortions during manufacture and/or assembly. (It may also develop after collector has been in operation over a period of time).
Misalignment of the reflector during assembly: The reflector may be rotated (or twisted) about the vertex-to-focus axis during assembly.
Dislocation of the receiver: The receiver may be misaligned with respect to the effective focus of the reflector during manufacture and/or assembly.

Tracker equipment may cause tracking bias/error due to its initial poor quality or tracking biases may develop after the collectors have been in operation for some time.

Profile errors may develop or increase due to wind loading, temperature effects, etc., during operation. Specularity of the reflective surface may increase with time, due to weathering or accumulated dust on reflector. Misalignment of the receiver with the effective focus may develop during operation due to one or a combination of the following:

Sagging or buckling of the receiver tube because of thermal expansion (if insufficient thermal expansion tolerance exists in the design).
Permanent expansion of the receiver as a result of thermal cycling over a period of time.
Change in location of the effective focus, due for example to increased profile errors in the reflector [26].

9. The global market in solar-thermal power

In order to operate solar power plants cost-effectively, it require a high proportion of direct solar radiation, therefore these systems can only be used in very sunny regions such as southern Europe, North Africa, South East Asia and South western USA. Although the market introduction of solar dish technologies has two fundamental barriers because of the total investments compared to other renewable technologies are very high and solar power projects having a relatively high risk due to limited experience, the majority of power plant projects are initiated only since 2004 in Spain, the USA and a few countries in North African countries. However, in the course of the current dynamic market development, many solar tower power plants are also being planned, as well as large-scale systems utilising dish/Stirling and Fresnel technology [27]. By 2050, electricity generated at solar-thermal power plants and wind farms in Africa and the Middle East is expected to cover 15–20% of Europe's energy needs. As mentioned before the potential sources would be solar-thermal power which is more economic (http://w1.siemens.com/). When there is rapid development of solar power globally, it is expected that there would be a cost reduction in electricity generation. Not only in industrial countries, the

developing countries will also increase their solar-thermal electricity in the next decade and there would be major contribution from solar power plant to generate renewable energy.

However, regarding the utilization of solar power, Malaysia is not in a very different situation when comparing to other neighbouring countries. In fact, Malaysia has a grand vision of being a developed country by 2020, by focusing to achieve betterment in various social, environmental and economic parameters. This also includes elimination of subsidies for non-renewable energy sources and instead providing some initial handholding for renewable energy sources should help among other things in rural electrification, environmental betterment and sustainable development. Needless to say that solar being the second major renewable energy source after biomass, would get a big boost [28]. In this case, the policy for developing countries [29] for instance is always available as a mechanism to enhance the utilization of RE, which include solar, apart from the local National Energy Policy drafted since the Fifth's Malaysia Plan.

10. Conclusion

The amount of power produced by a solar system depends upon the amount of sun light to which it is exposed. As the sun's position changes throughout the day, the solar system must be adjusted so that it is always aimed precisely at the sun and, as a result, produces the maximum possible power. Single axis tracking systems are considerably cheaper and easier to construct, but their efficiency is lower than that of two axes sun tracking systems. On the other hand, some solar systems require only two axes tracking, such as point focus concentrators. The solar dish concentrator technology has major advantages in economic and environmental benefits, together with delivered energy price stability. When highlighting the economic benefits, foreign exchange saving, creation of new jobs and increase in capital investment in the country. On the other hand, environmental benefits would be reduction in air pollution and greenhouse gas emissions. This will improve air quality, increase of public health, reduce haze and increase tourism.

References

[1] Anagreh Y, Bataineh A, Al-Odat M. Assessment of renewable energy potential at Aqaba in Jordan. Renewable & Sustainable Energy Reviews 2010;14:1347–51.

[2] Hang Q, Jun Z, Xiao Y, Junkui C. Prospect of concentrating solar power in China—the sustainable future. Renewable and Sustainable Energy Reviews 2008;12:2505–14.

[3] Al-Soud MS, Hrayshat ES. A 50 MW concentrating solar power plant for Jordan. Journal of Cleaner Production 2009;17:625–35.

[4] Fluri TP. The potential of concentrating solar power in South Africa. Energy Policy 2009;37:5075–80.

[5] Li J. Scaling up concentrating solar thermal technology in China. Renewable and Sustainable Energy Reviews 2009;13:2051–60.

[6] van Alphen K, van Sark WGJHM, Hekkert MP. Renewable energy technologies in the Maldives—determining the potential. Renewable and Sustainable Energy Reviews 2007;11:1650–74.

[7] Tsai W-T. Current status and development policies on renewable energy technology research in Taiwan. Renewable and Sustainable Energy Reviews 2005;9:237–53.

[8] del Río P, Unruh G. Overcoming the lock-out of renewable energy technologies in Spain: the cases of wind and solar electricity. Renewable and Sustainable Energy Reviews 2007;11:1498–513.

[9] Weisser D. Costing electricity supply scenarios: a case study of promoting renewable energy technologies on Rodriguez, Mauritius. Renewable Energy 2004;29:1319–47.

[10] Steinfeld A, Palumbo R. Solar thermo chemical process technology. In: Meyers, editor. Encyclopaedia of physical science & Tech, 15. Academic Press; 2001. p. 237–56.

[11] Tyner CE, Kolb GJ, Meinecke W, Trieb F. Concentrating solar power in 1999—an IEA/SolarPACES summary of status and future prospects; 2001. Retrieved December 05; 2009 from http://www.solarpaces.org/Library/docs/CSP_Brochure_2001.pdf.

[12] Duffie JA, Beckman WA. Solar engineering of thermal processes. John Wiley & Sons, Inc.; 2006.

[13] Jacobson E, Ketjoy N, Nathkaranakule S, Rakwichian W. Solar parabolic trough simulation and application for a hybrid power plant in Thailand. Retrieved December 08; 2009 from http://www.energy-based.nrct.go.th/Article/Ts-3%20solar%20parabolic%20trough%20simulation%20and%20application%20-for%20a%20hybrid%20power%20plant%20in%20thailand.pdf.

[14] US National Renewable Energy Laboratory. Parabolic trough solar field technology. Retrieved November 25; 2009 from http://www.nrel.gov/csp/troughnet/solar_field.html.

[15] Quaschning V. Understanding renewable energy systems. UK: Bath Press; 2005.

[16] Sulaiman MY, Bashria AY, Adam NM. Design of tracking system for UPM solar bowl. In: Sustainability for future through advanced technology. Universiti Putra Malaysia: Institute of Advanced Technology; 2008.

[17] Kaushika ND, Reddy KS. Performance of a low cost solar paraboloidal dish steam generating system. Energy Conversion & Management 2000;41:713–26.

[18] Koch H, Otto A, Schlump W. Stainless steel and the challenge of time [Presentation]; 2001. Retrieved November 15; 2009 from http://www.euro-inox.org/pdf/paper/Koch_Otto_EN.pdf.

[19] Keith L, Mike D. Solar thermal energy systems in Australia. International Journal of Environmental Studies 2006;63:791–802.

[20] Mayes L. Make Big paraboloid reflectors using plane segments; 2005. Retrieved December 15; 2009 from http://graffiti.virgin.net/ljmayes.mal/var/parabola.htm.

[21] Dendane A. Find the focus of parabolic dish antennas; 2007. Retrieved November 15, 2009 from http://www.analyzemath.com/parabola/parabola_focus.html.

[22] Kalogirou SA, Lloyd S, Ward J, Eleftheriou P. Design and performance characteristics of a parabolic-trough solar-collector system. Applied Energy 1998;47:341–54.

[23] Firak M. Comparative analysis of the solar dish electricity production. Thermal Science 2005;9:69–83.

[24] Exell RHB. Solar and wind energy—the intensity of solar radiation; 2000. Retrieved December 18; 2009 from http://www.jgsee.kmutt.ac.th/exell/Solar/Intensity.html.

[25] Quaschning V. The sun as an energy resource: technology fundamental. Renewable Energy World 2003;5:90–3.

[26] Guven HM, Bannerot RB. Determination of error tolerance of the optical design of parabolic troughs for developing countries. Solar Energy 1986;36:535–50.

[27] Mills D. Advances in solar thermal electricity technology. Solar Energy 2004;76:19–31.

[28] S. Sriram, Solar power in Malaysia—impediments to Growth; 2006. Retrieved November 30; 2009 from http://www.frost.com/prod/servlet/market-insight-top.pag?docid=67575287.

[29] Gabriele A. Policy alternatives in reforming energy utilities in developing countries. Energy Policy 2004;32:1319–37.

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